Lidar Instrument for Global Measurement of Mars Atmosphere

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Mars Scientific and Engineering Needs

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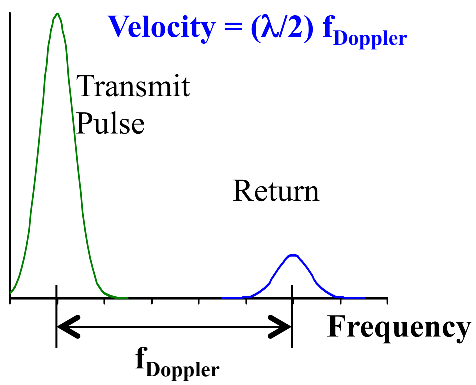
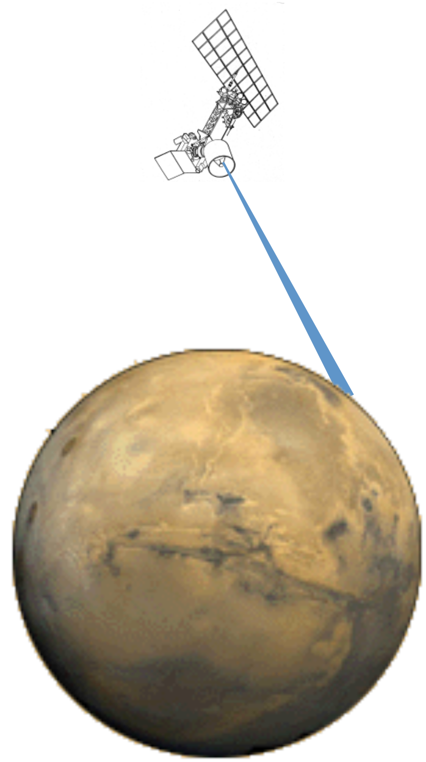
- Measurement of Mars atmospheric winds, density, temperature, and aerosol are essential for both “***Climate Research***” and “***Design of Future Large Robotic and Crewed Landing Missions***”
- Climate Research and Weather Models require:
  - Characterization of middle atmosphere structure, and its spatial and temporal variability
  - Understanding physical processes that control theses variations including effects driven by the Martian lower atmosphere
- Landing mission design requires:
  - Atmospheric density and its natural variability at altitudes ranging from surface to 100 km
  - Accurate wind velocity data from surface to 20 km

Mars Aerocapture

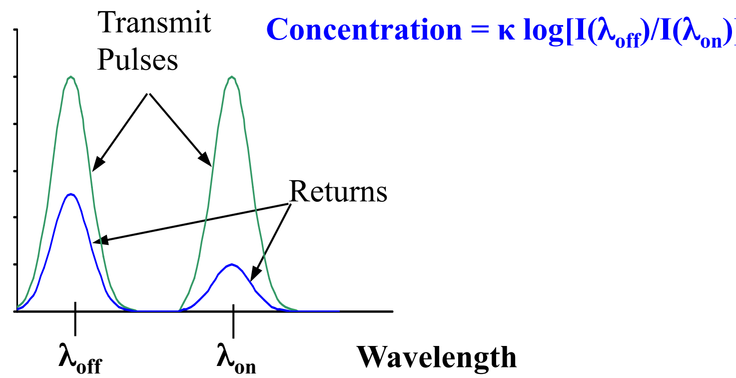
Lidar Atmospheric Measurement Techniques *LaRC*

Wind Measurement utilizing Doppler effect

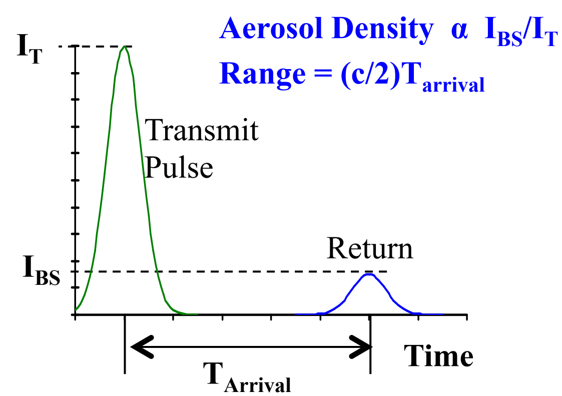




CO_2 Measurement utilizing Differential Absorption technique



Aerosol and clouds Measurements utilizing backscatter intensity



Multi-functional Coherent Doppler/DIAL Lidar

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- A multifunctional lidar instrument is being proposed that capitalizes on recent advances achieved by LaRC on highly efficient lasers and advanced coherent lidar components
- Lidar will be capable of providing global profiles of major Mars atmospheric parameters: ***Winds***, ***Density***, ***Temperature***, and ***Aerosols***.
- Proposed Mars lidar is substantially smaller than the ones proposed for Earth-orbiting lidars by taking advantage of:
  - Mars higher aerosol concentration (almost 2 orders of magnitude)
  - Low atmospheric density and lack of water vapor
  - Relaxed measurement accuracy and resolution
- Single instrument offers higher reliability and significant reduction in complexity, mass, volume, and power compared to multiple systems

Coherent Doppler/DIAL Lidar Instrument Design

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- Lidar instrument design will take advantage of recent advancements achieved by LaRC to meet the stringent mass, size, and power requirements of a Mars orbiting platform
  - High speed real-time processor allowing for more efficient high repetition rate and moderate pulse energy laser
  - Novel laser design with more than an order of magnitude higher efficiency compared with prior art
  - True quantum-noise limited heterodyne receiver
  - Wideband laser frequency modulator capable of on-command transmitter frequency control necessary for spectral scans and compensation of gross Doppler frequency shift due to platform orbit velocity

Doppler Lidar Real-Time Processor/Controller

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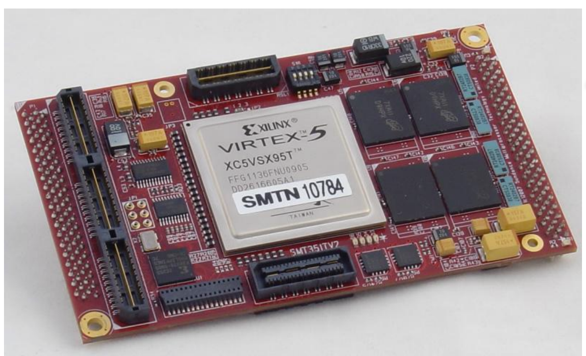
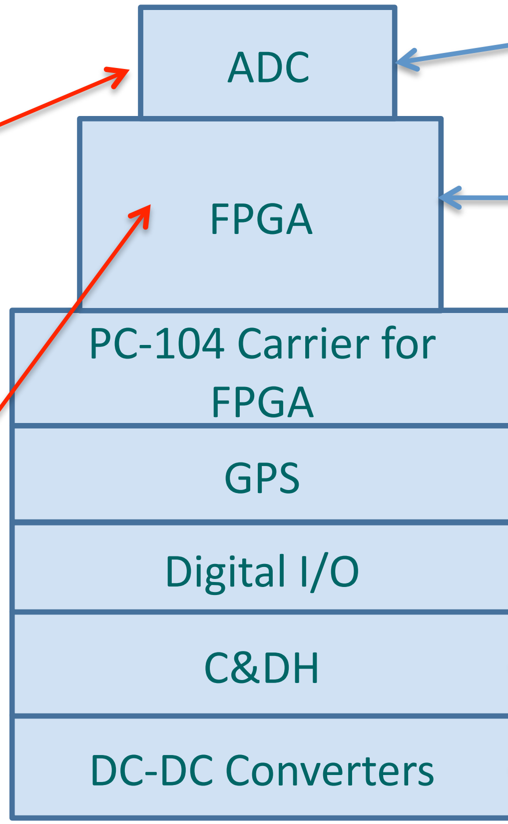
Current unit is capable of processing 250 MHz, 14-bit data at 100 Hz laser pulse rep rate. The ongoing development will produce a processor capable of 500 MHz sampling rate at 1 KHz laser rep rate by the end of FY'11.

ADC Board 4-channels, 14-bit 250 MHz

FPGA Board – Xilinx Virtex 5 SX95T





Receiver Analog outputs

Control Lines

7"x7"x5"

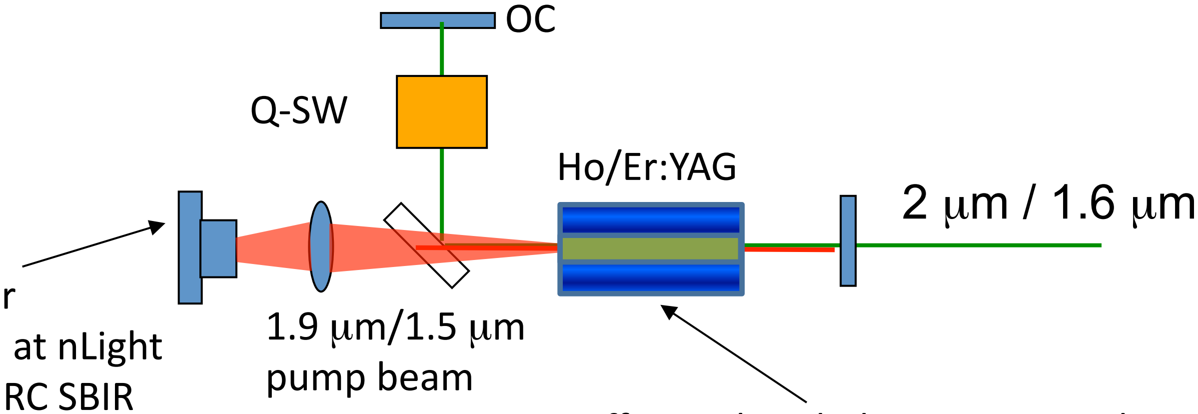
To initialize the system and transmit results

28 VDC

Ultra-efficient Compact Mid-IR Solid State Laser

An order of magnitude increase in efficiency is achieved by the combination of:

1. Long wavelength pump diode close to laser wavelength matched to absorption line (1.9 μm pump for 2-micron Holmium laser and 1.5 μm for 1.6-micron Erbium laser)
2. Diffusion-bonded composite laser rod and efficient collinear end pumping design



Ultra-efficient Compact Mid-IR Solid State Laser

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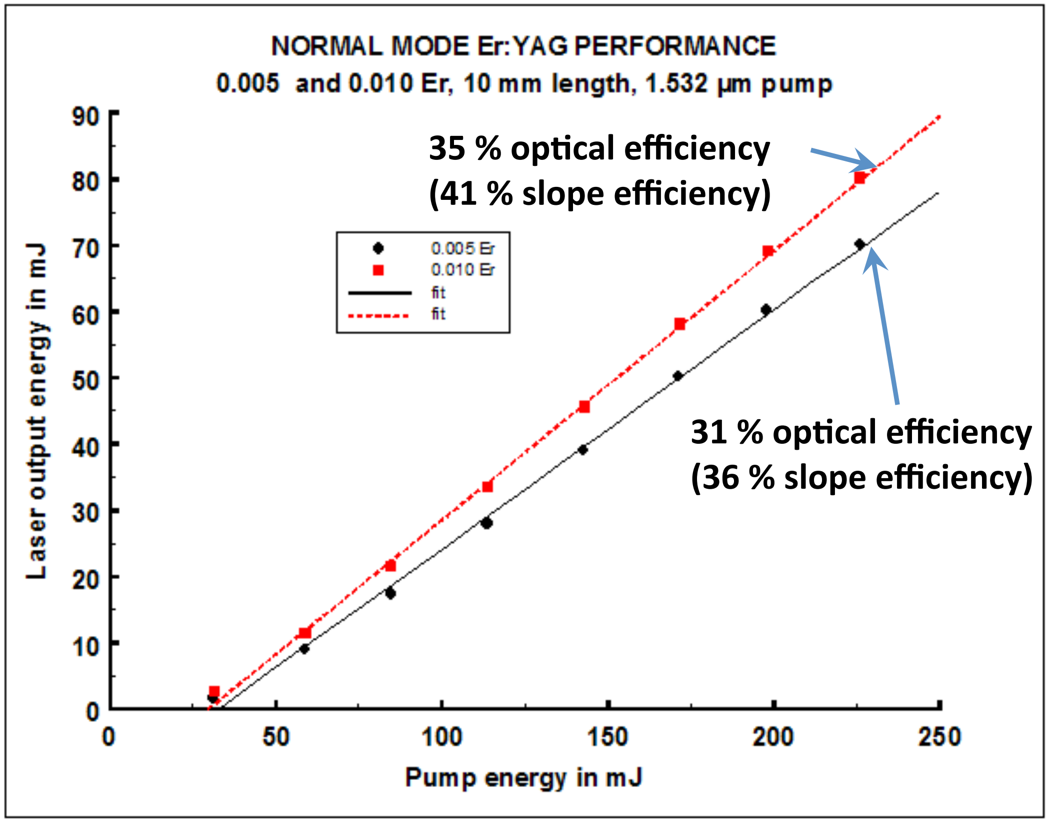
- High Laser efficiency demonstrated in normal mode using long wavelength, Volume Bragg Grating Locked, Diode pump laser
- Further optimization and the use of composite laser rod is expected to increase laser efficiency by another factor of 2

There will be some loss of efficiency when operated in Q-switched/single frequency mode required for lidar



Ultra-efficient Compact Mid-IR Solid State Laser

- Highly efficient and low-mass laser is a key enabling technology for a Mars-orbiting Lidar instrument

- Improving the laser efficiency will have significant impact of the instrument design:
    - Lower instrument power
    - Simplifies thermal management design
    - Lower mass
    - Allows trades in telescope size for laser pulse energy and repetition rate

Laser Selection Trades
(2-micron Holmium vs. 1.6-micron Erbium)

- Erbium laser allows for a simpler and more robust Lidar system design (utilization of COTS fiber optic components)
- Weaker absorption lines at Erbium wavelength allows greater CO_2 measurement range
- Holmium laser resonator design is less challenging (high energy storage capability and less susceptible to optical damage)
- Currently Erbium laser is the baselined choice
- System level design analysis and trades will guide the final laser selection

Quantum-noise Limited Heterodyne Receiver

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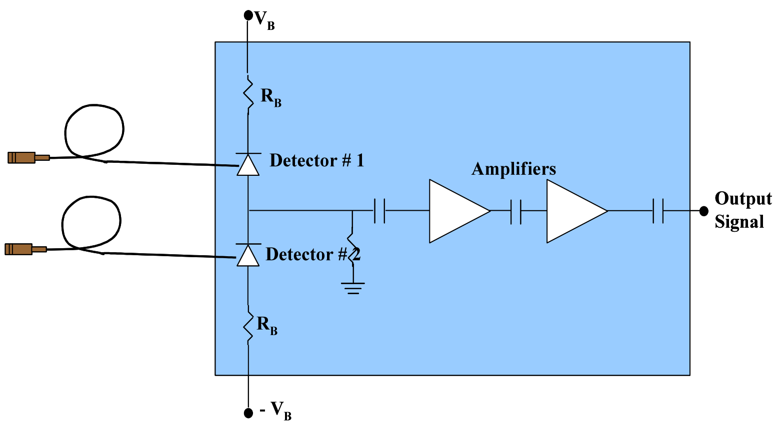
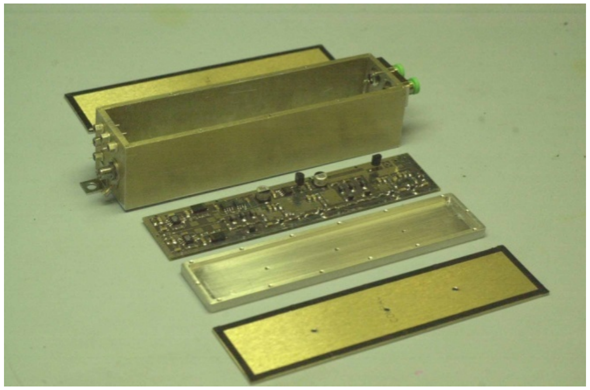
- Efficient Dual-Balanced Detector
- Optimized for highest heterodyne efficiency, i.e., high gain and low noise
- Fiber-coupled detectors for robust operation





Rough Performance Estimates

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Preliminary estimates based on the baseline specifications and 400 km orbit

- Winds
  - Accuracy 1m/sec
  - Measurement altitude from 60 km to surface (severe dust will significantly reduce the depth of measurements)
  - Vertical resolution 200 m below 10 km altitude and 2 km above 10 km
- Atmospheric density
  - Accuracy 5%
  - Measurement altitude from 90 km to 50 km
  - Vertical resolution 2 km
- Temperature
  - Accuracy 5 deg. K
  - Measurement altitude from 90 km to 50 km
  - Vertical resolution 2 km
- Aerosol Concentration
  - Accuracy 10%
  - Measurement altitude from 60 km to surface
  - Vertical resolution 200 m below 10 km altitude and 2 km above 10 km

SUMMARY

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- A relatively compact and low-power lidar instrument concept has been devised that is capable of providing all major Mars atmospheric parameters
- Major components of the Mars Atmospheric Lidar are being developed
  - Demonstrated high efficiency laser concept at 1.6 micron and 2 microns wavelengths
  - Several key lidar components developed and tested by ALHAT project (high speed real-time Doppler processor, receiver, frequency modulator, master oscillator laser)
- Future plan will depend on funding level
  - Complete lidar modeling and design trades in collaboration with Mars atmospheric scientists and landing mission designers
  - Integrate master oscillator laser with the breadboard transmitter laser and demonstrate tunable single frequency operation
  - Develop prototype laser
  - Design and build telescope and scanner
  - Design and build an engineering model of the complete system